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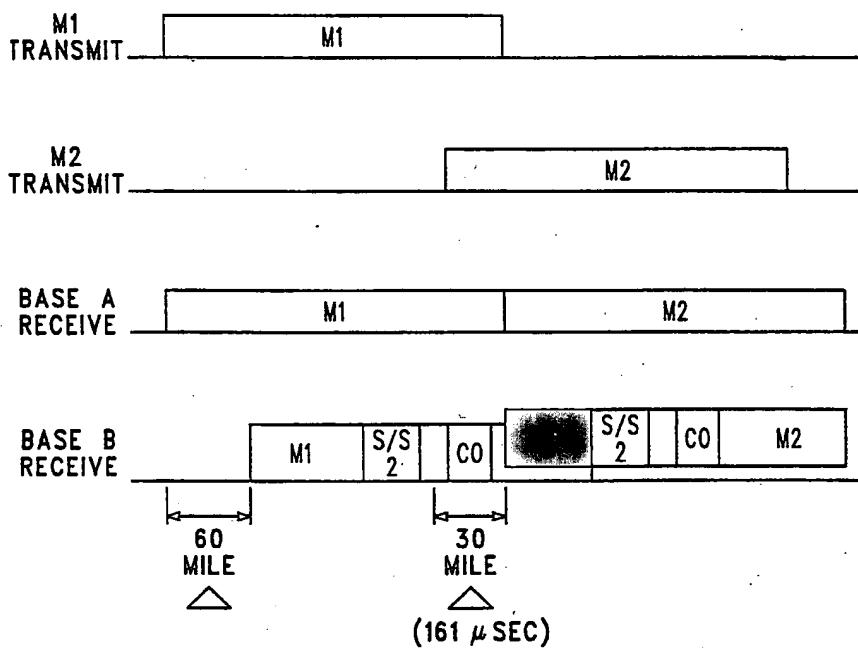
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## (54) Title: SYNCHRONIZATION AND EQUALIZATION IN A TDMA CELLULAR SYSTEM

## (57) Abstract

In a Time Division Multiple Access (TDMA) cellular system, there is provided a mechanism for synchronization and equalization comprising: providing synchronization information (S/S) sufficiently removed from the start of a TDM slot so as to maintain the integrity of that synchronization information (S/S) at adjacent cells and providing that synchronization information (S/S) not so far removed from the start of the slot as to necessitate adaptive equalization of information preceding the synchronization information (S/S) for sufficiently reliable recovery. The equalization is further enhanced by providing, roughly midway between the synchronization information (S/S) and the end of the slot, additional information (CC) upon which equalization may retrain. Accordingly, equalizers perform retrospective, non-adaptive equalization of information preceding the synchronization information (S/S), perform adaptive equalization of information following that synchronization information (S/S), and retrain utilizing known bit-sequences elsewhere within the TDM slot; the additional information (CC) comprises known bit-sequences identifying cells.



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## SYNCHRONIZATION AND EQUALIZATION IN A TDMA CELLULAR SYSTEM

### THE FIELD OF INVENTION

5 This invention is concerned with synchronization and equalization.

More particularly, this invention is concerned with system synchronization and equalization in a Time Division Multiple Access (TDMA) cellular system.

### BACKGROUND OF THE INVENTION

10 In land-mobile Time Division Multiple Access (TDMA) wireless systems, where the arrival times of subscriber transmissions must be arranged in time with the cell synchronization (advanced or retarded) to account for differing propagation delays due to the mobility of the subscriber, synchronization 15 information must be provided to the subscriber to acquire and maintain all transmissions synchronized into the Time Division Multiplexed (TDM) slot structure of the communications channel.

20 One way is to provide sufficient guard time before the subscriber transmission of any useful information to accommodate the furthest expected transmission. Then, that subscriber is commanded to advance its subsequent transmissions to become synchronous with the cell. Known synchronizing sequences are incorporated within all 25 transmissions and used for maintaining cell synchronization.

The problem in cellular TDMA systems is that adjacent cells must aperiodically monitor subscribers in neighboring cells for

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handoff candidacy (as the subscriber moves from cell to cell). Thus, as illustrated in Figure 1, when subscribers have been synchronized to their host cell (taking account of their respective range from the host), subscriber transmissions are 5 out of synchronism with those of adjacent cells (because of the probable opposite relationship of their ranges from the adjacent cell site). For example, if Mobile subscriber 2 (M2) has its transmissions advanced (as in Figure 2b) by eight bits (at 48 Kbps - kilobits per second) to account for the thirty mile 10 difference in range from cell site A in order to arrive in time slot 2 following (Figure 2c) that of Mobile subscriber 1 (M1), Figure 2a, M2's transmissions will have advanced toward M1's. Yet, for adjacent cell B, M1's transmissions should have been advanced toward M2's to accommodate the differences in their 15 respective ranges from cell site B. Accordingly, the end of M1's transmissions in time slot 1 will collide with the beginning of M2's transmissions in time slot 2 as received by cell site B (as illustrated by the hatched area of Figure 2d). Thus, synchronizing information (the information of interest to the 20 adjacent cell) cannot appear at the start of a time slot, or it will be subject to collision (in the hatched area of Figure 2d).

Wireless transmissions reflect off numerous objects and obstructions on their way to the receiver. As a result, for proper detection of the individual bits of information 25 transmitted, equalizers must align in time the various time-dispersed echoes it receives and make decisions about each bit. Accordingly, the receiver correlates the synchronization sequence present within each echo against a known sequence and, having the instant of correlation of each echo, is able to 30 align them in time and obtain time-dispersal coefficients for equalization. Having the instant of correlation and the time-dispersal function, it is possible to detect subsequent information (and to retrospectively detect preceding information, if stored) until the propagation conditions change

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and alter the time-dispersal characteristics. Adaptive equalization, although computationally intensive, adapts the coefficients to track the time-dispersal characteristics over time; the longer the time (measured by number of bits) since 5 the arrival of the synchronization/equalization sequence, the greater the need for adaptive equalization. A more extensive discussion of adaptive equalization can be found in: *Shahid Qureshi, Adaptive Equalization, IEEE Communications Magazine, March 1982, 0163-6804/82/0300-0009, pp. 9-16.*

10 The Pan-European Digital Cellular system is a TDMA cellular system that employs a mid-amble -- synchronizing information appears in the middle of the time slot. Our problem never arose there because fixed equalization at their data rate and slot length is adequate for reliable detection in both the 15 forward time direction and the reverse time direction. However, at our data rate and slot length, *adaptive* equalization would be required for reliable detection in the reverse time direction, adding substantially to the complexity of the equalizer and requiring a sizeable memory to store the time- 20 dispersed echoes preceding the synchronization sequence.

This invention takes as its object to overcome these shortcomings and to realize certain advantages presented below.

#### SUMMARY OF THE INVENTION

25 In a Time Division Multiple Access (TDMA) cellular system, there is provided a mechanism for synchronization and equalization comprising: providing synchronization information sufficiently removed from the start of a TDM slot so as to maintain the integrity of that synchronization information at 30 adjacent cells and providing that synchronization information not so far removed from the start of the slot as to necessitate

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adaptive equalization of information preceding the synchronization information for sufficiently reliable recovery.

5 The equalization is further enhanced by providing, roughly midway between the synchronization information and the end of the slot, additional information upon which equalization may retrain.

10 Accordingly, equalizers perform retrospective, non-adaptive equalization of information preceding the synchronization information, perform adaptive equalization of information following that synchronization information, and retrain utilizing known bit-sequences elsewhere within the TDM slot; the additional information comprises known bit-sequences identifying particular cells.

#### DESCRIPTION OF THE DRAWINGS

15 Additional objects, features and advantages of the invention will be more clearly understood and the best mode contemplated for practicing it in its preferred embodiment will be appreciated (by way of unrestricted example) from the following detailed description, taken together with the 20 accompanying drawings in which:

Figure 1 is a graphic illustration of the problem solved by this invention and the environment in which the preferred embodiment of the invention operates.

25 Figures 2a through 2d are timing diagrams of the problem encountered and the solution offered by the preferred embodiment of the invention.

One of any number of exemplary embodiments of such an apparatus is illustrated in US Pat. No. 4,829,543 to Borth et al.

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and assigned to Motorola, the instant assignee, and reproduced herein as a prior art figure for the convenience of the reader.

#### DETAILED DESCRIPTION

5 This invention recognizes that, by positioning synchronization information (S/S) sufficiently beyond the start of the TDM slot, the integrity of the synchronization information will be maintained and will not be collided with by the end of the previous slot (the hatched area of Figure 2d). Moreover, 10 positioning the synchronization as far forward as is consistent with avoiding collision allows any retrospective detection of data to be done by a fixed coefficient equalizer rather than an adaptive equalizer. This is far less computationally intensive and substantially reduces the memory requirements (because far less information must be retained for retrospective 15 processing).

In the preferred embodiment of the invention, synchronization information is provided sixteen bits (2 radii of range difference at 30 miles at 48 Kbps) after the start of the time slot (i.e., just beyond the hatched area of Figure 2d), which provides the 20 extra guard time required at the adjacent cells. Thus, only sixteen bits need be stored for retrospective processing (thereby substantially reducing memory requirements) and, since the time-dispersal characteristics are far less likely to change significantly over that sixteen-bit interval, the necessity 25 for retrospective *adaptive* equalization is eliminated (thereby substantially reducing the complexity of the equalization). Control information (information that is unimportant to the adjacent cell) is transmitted in the beginning sixteen bits of the slot.

30 As further improvement, known bit-sequence identifying the host cell (CC -- "color code" or Digital Supervisory Audio Tone -

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DSAT) that are regularly exchanged as an integral part of all transmissions can be transmitted somewhat later in the slot -- somewhere (avoiding the hatched area of Figure 2d) -- such that it also is available to the adjacent cell. So placed, it would 5 be useable for retraining the adaptive equalizer as it correlates on the sequence; for that purpose, perhaps somewhere midway between the synchronization sequence and the end of the slot would be optimal.

An attendant advantage of such a *separate* cell identification 10 field is that the field may be readily detected without decoding of other parts of the transmission (e.g., the digitized voice message or error correction information). Thus, this field can be readily utilized by rudimentary, nonvoice-capable scanning receivers (for confirmation of the candidacy of a subscriber for 15 handoff), resulting in substantial hardware and processing simplification. Moreover, this field, received intact due to its advantageous position within the time slot, can be readily utilized for positive muting (voice muting) of co-channel interferers (with different "color codes") that would otherwise 20 result in inadvertent reconstruction of voice messages from other cells.

The attendant advantages of this invention include elimination 25 of retrospective *adaptive* equalization (and its concomitant computational penalties) and a substantial reduction in memory requirements.

In a Time Division Multiple Access (TDMA) cellular system, there has been provided a mechanism for synchronization and equalization comprising: providing synchronization information sufficiently removed from the start of a TDM slot so as to 30 maintain the integrity of that synchronization information at adjacent cells and providing that synchronization information not so far removed from the start of the slot as to necessitate

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adaptive equalization of information preceding the synchronization information for sufficiently reliable recovery.

The equalization has further been enhanced by providing, roughly midway between the synchronization information and 5 the end of the slot, additional information upon which equalization may retrain.

Accordingly, equalizers perform retrospective, non-adaptive equalization of information preceding the synchronization information, perform adaptive equalization of information 10 following that synchronization information, and retrain utilizing known bit-sequences elsewhere within the TDM slot; the additional information comprises known bit-sequences identifying particular cells.

The foregoing discussion is only meaningful for subscriber-to-15 system communication as only those are of interest at the adjacent cell.

The means for implementing the invention presented above are easily constructed and well understood by those ordinarily skilled in this field. One of any number of exemplary 20 embodiments of such an apparatus is illustrated in US Pat. No. 4,829,543 to Borth et al. and assigned to Motorola, the instant assignee, and reproduced herein as a prior art figure for the convenience of the reader. While the preferred embodiment of the invention has been described and shown, it will be 25 appreciated by those skilled in this field that other variations and modifications of this invention may be implemented; these and all other variations and adaptations are expected to fall within the ambit of the appended claims.

## SYNCHRONIZATION AND EQUALIZATION IN A TDMA CELLULAR SYSTEM

### CLAIMS

What we claim and desire to secure by Letters Patent is:

- 5 1. A method of synchronization and equalization in a Time Division Multiple Access (TDMA) cellular system comprising:
  - 10 providing synchronization information removed from the start of a TDM slot so as to avoid collisions of that synchronization information at adjacent cells
  - 15 and providing that synchronization information not so far removed from the start of the slot as to involve adaptive equalization of information preceding the synchronization information.
2. A method as claimed in Claim 1 above, further comprising:
  - 20 providing subsequent additional information not subject to collision at adjacent cells upon which equalization may retrain.
3. A method as claimed in Claim 2 above, wherein the additional information is provided about a point midway between the synchronization information and the end of the slot.
- 25 4. A method as claimed in Claim 2 above, wherein the additional information comprises bit-sequences identifying cells.

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5. A method as claimed in Claim 4 above, wherein the bit-sequences are utilized for confirming handoff candidacy.
6. A method as claimed in Claim 4 above, wherein the bit-sequences are utilized for voice muting.
- 5 7. A method of synchronization and equalization in a Time Division Multiple Access (TDMA) cellular system comprising:

10 providing synchronization information removed from the start of a TDM slot so as to avoid collision of that synchronization information at adjacent cells,

15 providing that synchronization information not so far removed from the start of the slot as to involve adaptive equalization of information preceding the synchronization information

and providing subsequent additional information not subject to collision at adjacent cells upon which equalization may retrain.

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8. A method of synchronization and equalization in a Time Division Multiple Access (TDMA) cellular system comprising:

5 providing synchronization information removed from the start of a TDM slot so as to avoid collision of that synchronization information at adjacent cells,

10 providing that synchronization information not so far removed from the start of the slot as to involve adaptive equalization of information preceding the synchronization information

15 and providing, about a point midway between the synchronization information and the end of the slot, additional information upon which equalization may retrain.

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9. A method of synchronization and equalization in a Time Division Multiple Access (TDMA) cellular system comprising:

5 performing retrospective, non-adaptive equalization of information preceding the synchronization information

and performing adaptive equalization of information following that synchronization information.

10. A method as claimed in Claim 9 above, further comprising:

10 retraining the adaptive equalization utilizing known bit-sequences elsewhere within the TDM slot.

11. A method as claimed in Claim 10 above, wherein the known bit-sequences comprise sequences identifying cells.

12. A method of synchronization and equalization in a Time Division Multiple Access (TDMA) cellular system comprising:

20 performing retrospective, non-adaptive equalization of information preceding the synchronization information,

performing adaptive equalization of information following that synchronization information

25 and retraining the adaptive equalization utilizing known bit-sequences elsewhere within the TDM slot.

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13. An apparatus for synchronization and equalization in a Time Division Multiple Access (TDMA) cellular system comprising:

5 means for performing retrospective, non-adaptive equalization of information preceding the synchronization information

coupled with means for performing adaptive equalization of information following that synchronization information.

10 14. An apparatus as claimed in Claim 13 above, further comprising:

15 coupled with the adaptive equalization means, means for retraining the adaptive equalization utilizing known bit-sequences elsewhere within the TDM slot.

15. An apparatus as claimed in Claim 14 above, wherein the known bit-sequences comprise bit-sequences identifying cells.

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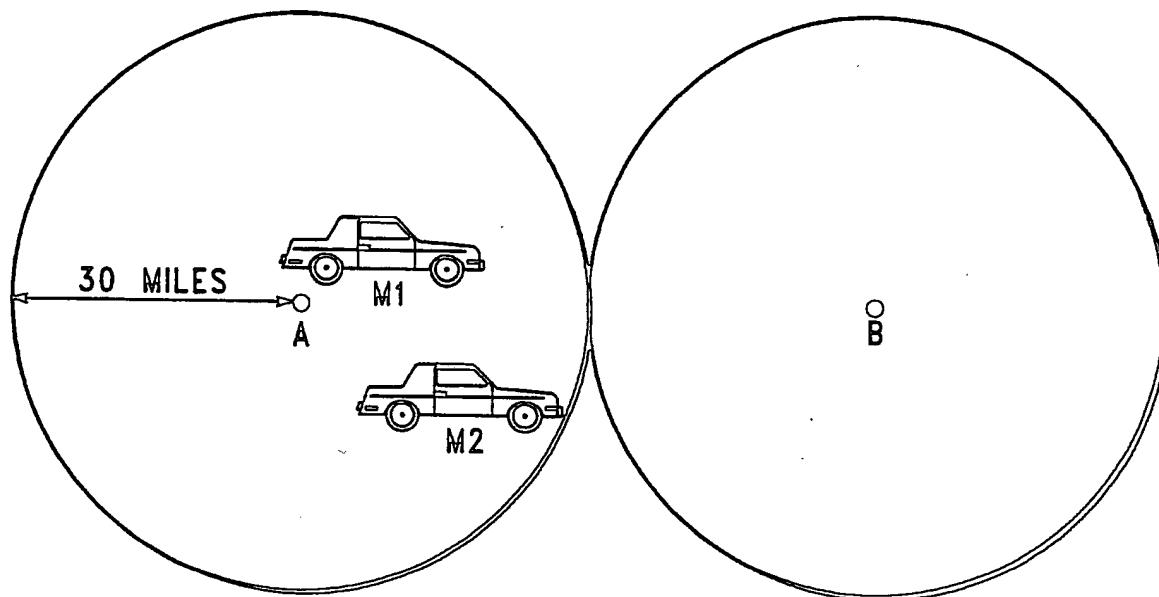


FIG. 1

FIG. 2 A

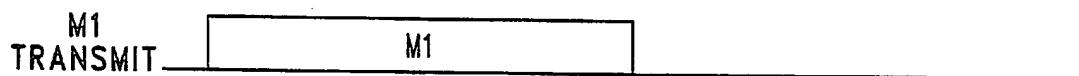


FIG. 2 B



FIG. 2 C

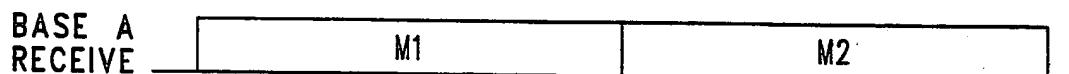
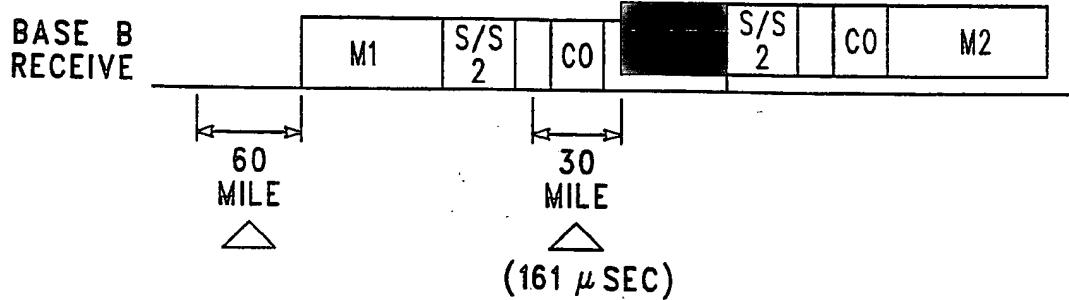
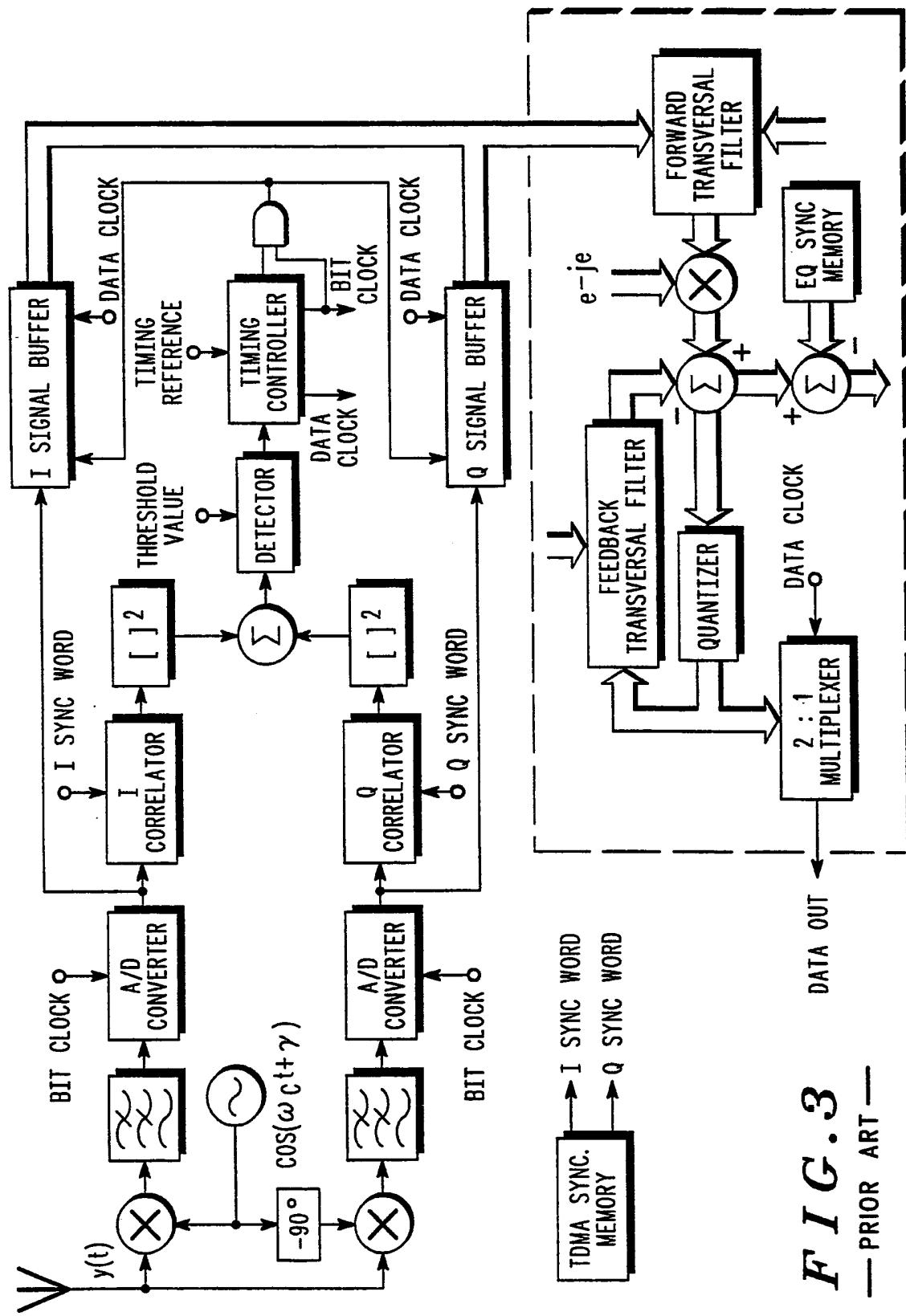


FIG. 2 D



SUBSTITUTE SHEET

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SUBSTITUTE SHEET

**FIG. 3**  
— PRIOR ART —

# INTERNATIONAL SEARCH REPORT

International Application No. PCT/US90/03570

## I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) <sup>6</sup>

According to International Patent Classification (IPC) or to both National Classification and IPC  
 IPC (5): H04J 3/16; H04Q 7/00; H04Q 9/700; H04M 11/00  
 U.S.CI.: 370/95.3; 455/33; 379/60

## II. FIELDS SEARCHED

Classification System	Minimum Documentation Searched <sup>7</sup>	
	Classification Symbols	
U.S.CI.	370/95.1, 95.3, 100.1, 104.1, 105, 105.1, 110.1, 111 379/59, 60, 63; 455/33, 38, 54; 375/107, 108	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>		

## III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>9</sup>

Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
A	US, A, 4,829,543 (BORTH et al.) 09 May 1989. See entire document.	9-15
A	US, A, 4,754,453 (EIZENHOFER) 28 June 1988. See entire document.	1-8
A	US, A, 4,414,661 (KARLSTROM) 08 November 1983. See entire document.	1-8
A	US, A, 4,252,999 (ACAMPORA et al.) 24 February 1981. See entire document.	1-8

\* Special categories of cited documents: <sup>10</sup>

"A" document defining the general state of the art which is not considered to be of particular relevance  
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 "P" document published prior to the international filing date but later than the priority date claimed

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

## IV. CERTIFICATION

Date of the Actual Completion of the International Search

26 July 1990

Date of Mailing of this International Search Report

02 OCT 1990

International Searching Authority

ISA/US

Signature of Authorized Officer

*Alpus H. Hsu* *NGOC-HO*  
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